NATIVE BANANA FIBER (*Musa acuminata)* AS SUSTAINABLE ALTERNATIVE FOR COTTON IN TEXTILE/FASHION INDUSTRIES

A SYNOPSIS

Submitted by

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1. INTRODUCTION

Textile Industries is one of the most essential industries in the world. We need clothing to survive but we also need to produce clothing in a manner that preserves the planet in which we live to survive as well. Textiles are essential to the construction of clothing. Determining sustainability, fashion industry appeal, and consumer desirability are important to understand which textiles are going to be essential in the coming years as companies and consumers continue to take on a sustainability consciousness. Natural fiber is one of the possibilities to give good and sustainable textiles. Cotton is the best fiber one among those, called the king of the fibers. In the current scenario, none of the fiber can get cotton properties. It has better uniqueness than other fibers. Even though, still the research is going on. Some fibers have very close properties to cotton such as Banana, Bamboo, Flax, Ramie, Pineapple and Jute. These fibers are extracted from stem and leaf and some other ways are used to be extracted. Now the demand of cotton fiber is so high in the current scenario. World scientists and industrialists are seeking alternative fibers. Right now, synthetic fibers are fulfilled the demand but anyway it is not good for the environment because it does not have degradable property. Hence the fiber needs for alternative of cotton and must be sustainability [1]. It should be a continuous resource. Then only it can be fulfilled.

The fiber content is available in all kinds of plants, but it is hard to extract. Banana and bamboo is the best option and sisal, pine apple leaf, kenaf fibers are the second options. The product source availability must be sustainable. Then only able to use continuously and should not affect the production planning. Bamboo is mostly imported from other countries, especially from China. Bamboo is suitable to use as a filament or filament fibers. In India the source of bamboo is little bit less than China and other countries such as Russia, USA, South American countries, Indonesia, Australia etc., Pineapple and sisal availability are very less and Kenaf fiber plant is available only in the middle part of India. So, sustainability may not be possible for this product, also these are growing season wise. The cultivation is according to the climatic conditions [2]. Apart from those fibers, banana fiber has some possibility to be used instead of cotton. The first aspect is, it is one of the big biomasses across the world and the significant thing is India is a leading producer of banana cultivation and sharing

almost 35% of the world market. Once cultivated, almost 4/5 of the biomass per plant was generated. The second aspect is, naturally banana plant contains good antibiotic properties in all components. Those are used for some pharmaceutical applications. So, it is good for human skin and health. Additionally, it has given cooling to the human body. The third important aspect is banana fiber has abundance fiber content in stem and simple way to extract. It is one of the renewable and sustainable resources. Hence banana fiber is a possibility to fill the place of cotton, not in 100% at least is able to satisfy 25-40 %. Hence banana might be a suitable resource for this demand and able to fulfill the demand not in 100% at least 10-20%, when compared to other fibers.

The native banana variety (*Musa acuminata*) that is *Musaceae* genius plant-based textiles are the focus of this research. This is cultivating in the southern part of India. It has many qualities that make it a sustainable textile. Banana trees take nine months to grow a bunch of bananas. It takes another two to three months for the bananas to ripen after that. Once this cycle is complete, the mother plant dies. Therefore, it has to be cut down. The banana fiber can then be extracted from the banana pseudo stem, which looks similar to a tree trunk, and is useless after the fruit is harvested. This is what can be used to make fabric. It is also sustainable, biodegradable, strong, fine, and could be an alternative to silk [3]. So, a dead waste product from banana production, which is already being grown on a large scale globally, can be turned into fabric. According to the textile industries, the banana extracted fiber is commonly called *Musa* textiles (*Abaca fiber),* a variety of banana plants, while it does not produce fruit also has sustainable qualities [4]. It may not be grown for food but there are environmental benefits such as erosion control, biodiversity rehabilitation, is used for intercropping, using waste materials as fertilizer. Banana fiber-based textiles have many qualities that make it a sustainable textile.

Textiles are also being produced and used in multiple industries. However, despite many positive factors that banana fiber has as a textile for the fashion industry, it is not well known and underused. There have been some articles on fashion sites and other media like the Guardian that have spoken about banana fiber as an innovative and sustainable fabric solution. There are a few small companies that are using banana fiber as a main textile in their apparel. Australian and USA men’s underwear brand was using banana fiber blended into some of their textiles for use in a line of underwear.

Since then they have ceased the use of fiber. However, it is a very obscure textile in the fashion industry, even with the rise in sustainability awareness. Considering this information, the purpose of the study is to discover whether banana fiber and the fabric it creates is viable in the fashion industry by viewing the fabric from multiple perspectives. Then, if viable, understand what products may be produced with banana fiber for the highest benefit. The nature of this study is exploratory and therefore aims to discover what might not be already exist. It can help to create new possibilities in textile and fashion industries and can be a good replacement for cotton.

2. LITERATURE REVIEW

Textiles are the foundation of the fashion industry. Without them we would not have clothing, especially comfortable clothing. Therefore, knowing the foundation of textiles is very important for consumers as well as for the purpose of this study. Subagyo and Chafidz [4] discussed about all textiles under two main categories, those made with natural fibers and those made with manufactured fibers. Fibers are “hairlike” stands similar to human hair. Kannigadevi et al. [5] explained there are three main branches of fibers: Natural, regenerated, and synthetic. Natural fibers are divided into 2 categories: Plant and animal. Plant based fibers are cellulosic wild animals’ fibers are protein based. Common natural cellulosic fibers include cotton, flax, hemp and bamboo. Fibers obtained from animals are protein based and either come from hair, as is the case with wool, cashmere and alpaca, or a secretion, silk being an example. Saxena and Chawla [6] classified manufactured fibers fall into three categories: regenerated, synthetic, and bio-plastic. Regenerated fibers also contain cellulose. These fibers are made from naturally occurring polymers in which the cellulose is broken down and reformed into a new matter . The cellulose for this process is taken from wood pulp. Kavitha and Aparna [7] explained Rayon and lyocell are two examples. Newer regenerated fibers that use a protein base are casein from milk, soy and corn. Gupta et al. [8] mentioned the next category is synthetic. These fibers are created from petroleum (petrochemicals) and engineered for certain qualities, essentially a form of plastic. Nylon and polyester are synthetic fibers.

Ramamoorthy et al. [9] elaborate the fibers are processed, they are spun into yarns. Yarn is made by twisting small fibers laid together to form one long strand.

These yarns can then be woven or knitted to form fabric or textiles. Determination the Sustainability of Textiles is to development or agriculture of sustainable fibers is one area of focused effort toward sustainability within the fashion industry. Defining a sustainable fiber can be difficult. Kanimozhi and Rajeshkumar [10], the author addressed some of the questions that one must consider when determining if indeed a fiber is sustainable and referred sustainability in the fashion world has become a hot-button topic. It has also become a very confusing ethical question. Does recycling mean sustainability? Is the fiber sustainable if it grows without pesticides or is it enough to simple reduce water usage and is the fiber still sustainable, if it grows without the use of pesticides but dyed in a chemical bath, finished with formaldehyde, and then shipped in plastic. As per the author Vigneswaran et al. [11] one may assume that natural fibers are automatically more sustainable but that is not always the case. The author lists some production concerns that determine a sustainable fiber: energy used in both growth or production of the fiber, the process necessary to make it usable, societal impact, environmental strain, dye and finishing processes required, care for the produced textile disposal method (can it be recycled or is it biodegradable). Rana et al. [12] statement is, several sections were addressed some of these questions including current agricultural practices for banana fiber as well as fiber and fabric production.

Subramanya et al. [13] narrate about bananas having a long history as a textile. It is a leaf fiber which places it in same category of the natural fibers' sisal and pineapple. The use of banana fiber in textiles has been occurring since the 13thcentury. Katrien Hendrickx's book from 2007 discusses the origins of bashofu fabric or banana fabric in the Ryukyu Archipelago of Japan and its use potentially as early as the 1300's. In the Edo period (1600-1868) bashofu was used for a popular summer dress called the Kamishimo (Bashofu banana fiber cloth).

Saravanan and Gnanavel [14] describes some of these garments were worn for special events or ceremonies and were valued highly along with silk and cotton. Preethi and Balakrishna [15] mentioned that in the Philippines, *abaca* has been used in traditional textiles, particularly weft-based textiles. Another author Aziz et al. [16] discusses *abaca* being used in light weight, delicate fabric along with pineapple for catholic religious garments which were decorated with embroidery. Banana fiber is taken from the pseudo stem of a banana plant.

Ronald Aseer et al. [17] investigated the fiber content is available in all elements but the extraction is so hard from other elements except banana stem or stalk. Banana fiber can be removed from the pseudo stem through several different processes manually or machine or through retting. Shivashankar et al. [18] explained about the machine process allows for better quality fibers to be obtained from the pseudo stem and can produce up to 20kg a day per machine as opposed to 500gms in the manual process. A decorticator machine which has rotating parts with blades attached is commonly used. Pieces of the pseudo stem are fed through the machine and come out crushed and pulpy. They are then degummed, washed, and dried.

Mohiuddin et al. [19] discussed about the retting is a process often used on bast fibers to remove "non-cellulosic material attached to fibers to release individual fibers. There are five different kinds of retting, "dew, water, enzymatic, mechanical and chemically retting". Retting has been shown to be an efficient way of collecting textile fibers from banana pseudo stems. It also allows for the recovery of more fibers compared to the mechanical extraction process. The pseudo stem has several different qualities of fiber due to the layers that are formed in the stem. The outer layers (4-6) produce a course fiber; the middle layers (6-8) produce a shiny and soft fiber while the inner layers have an even softer fiber.

Barman et al. [20] demonstrated the fiber application, especially sanitary napkin process and how it can be converted as yarn and yarn into fabric. To determine the viability of banana fiber, it is also important to evaluate how it compares to other 'sustainable' natural fibers. Bhatnagar et al. [21] elaborates about banana fiber were compared to bamboo, organic cotton, and pine-tex in terms of a few aspects of sustainability: Biodegradability, water consumption during growth, pesticides, fiber processing, and consumer care. Dying cellulosic fibers is generally highly water intensive, heat intensive, and requires many chemicals overall. The process also involves both a pre- and post-treatment requiring water and energy. Therefore, for the sake of this brief comparison, the dye process is considered similar in impact and not discussed. In terms of sustainability, first off, banana fiber is biodegradable.

Hassan et al. [22] explained, banana fiber does not have additional water consumption, being an agricultural byproduct and they typically grow in tropical areas

where the rainfall is from 78-98 inches a year. It even is described about the composite's preparation from banana fiber. However, since banana plants are frequently irrigated, water use should be considered. Kumar et al. [23] discussed about the medical application of banana fibers and the water footprint for their bananas grown in Costa Rica and Honduras reported that in Costa Rica, there is no blue water at all since they are entirely rain fed but the plantations in Honduras are irrigated with blue water. In both Honduras plantations studied, there was less than 20% blue water per kg of bananas when considering the total of blue and green water the plants used in the growth phase. Padam et al. [24] compared the product development from the other fibers. Additionally, the study detail explained about the fiber property and applications.

3. RESEARCH PROBLEM

Based on the literature review the following research gaps are identified,

- There is no comparison studies on absorption and antibacterial property between banana (*Musa acuminata*) and cotton fibers in this families.
- There are few works carried out on development of eco-friendly sanitary napkin using raw and alkali treated banana fiber and compared with cotton made napkin.
- Blended with cotton (50:50) and pure banana open end yarn is not yet produced by utilizing native banana fiber (*Musa acuminata*).
- There is no study on the natural fabric made from banana combined cotton in this family (Musa acuminata).

4. OBJECTIVE

- To extract the fiber from pseudo-stem of banana plant (*Musa acuminata*) and treated with alkali (4% NaOH).
- To study the physical, chemical, absorption and antibacterial properties of raw, alkali treated banana and cotton fibers.
- To develop the sanitary napkin using raw and alkali treated banana fibers and investigating their performance with cotton napkin.
- To develop the yarn and fabric from banana blended with cotton fiber and investigating their mechanical properties.

5. METHODOLOGY

Research Methodology

The research methodology has followed in this research work that is mentioned in Figure 1. The banana fiber extraction, properties, application, and comparison studies has been explained detailed in this methodology. The banana fiber-based products have been compared with the existing cotton product such as fiber, yarn, and fabrics.

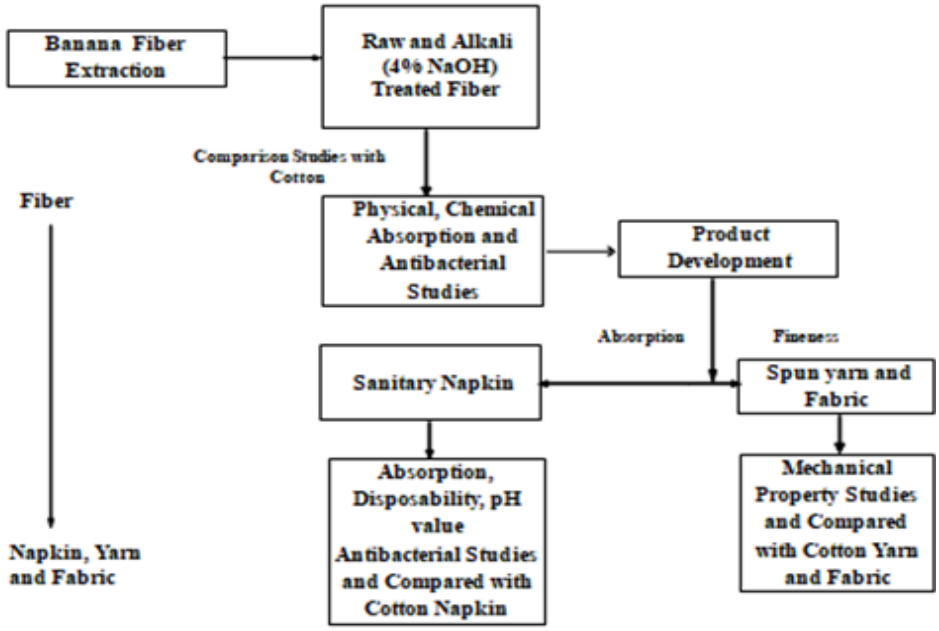

Banana Fiber Extraction
Raw and Alkali (4% NaOH) Treated Fiber
Comparison Studies with Cotton
Fiber
Physical, Chemical Absorption and Antibacterial Studies
Product Development
Absorption
Fineness
Sanitary Napkin
Spun yarn and Fabric
Napkin, Yarn and Fabric
Absorption, Disposability, pH value Antibacterial Studies and Compared with Cotton Napkin
Mechanical Property Studies and Compared with Cotton Yarn and Fabric

Figure 1 The Research Methodology for Native Banana Fiber Products and Properties

Banana raw and treated fiber along with cotton fiber were used in this research and investigating their physical, chemical, absorption and antibacterial properties. Finally, the products have been developed and compared their properties.

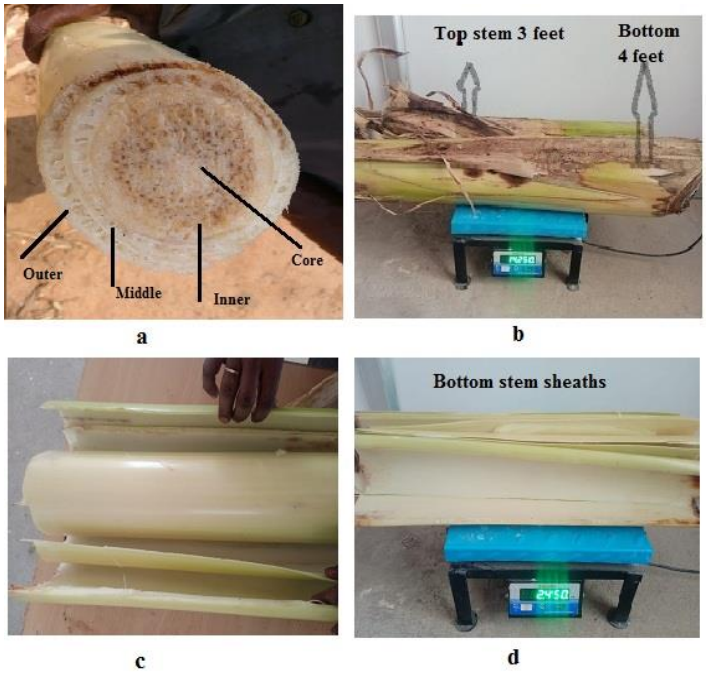
6. MATERIAL AND METHODS

6.1 Banana Plant and Extraction Machine

The initial source of the material was collected from the agricultural land from South India. The native banana tree or plant is a main resource of this research. The plant (*Musa acuminata*) and stem are mentioned in Figure 2. The stem cross section

view and that weight is also seen. The banana pseudo stem has 4 kinds of layers. In this research the outer and middle sheaths were only utilized. The mechanical extraction was followed in this research.

Banana Plant



a) Banana Stem b) Stem weight c)Stem Sheath d) Weight of outer and middle sheaths

Figure 2 The native banana plant and sheaths removal from the stem

The extraction machine and fiber extraction process has mentioned in the Figure 3. This is coming under semi-automatic machine, which was developed by SP Grace Natural, South India.

6.2 The biomass and fiber recovery level

The biomass has been calculated as per hectare. This was done for Musa acuminata variety and compared with other wild species variety based on other literature. The fiber recovery percentage is determined by the formula below.

$$\text{Fiber recovery percentage} = \frac{\text{Weight of the fiber (g)}}{\text{Weight of the extractable banana stem (g)}} * 100$$

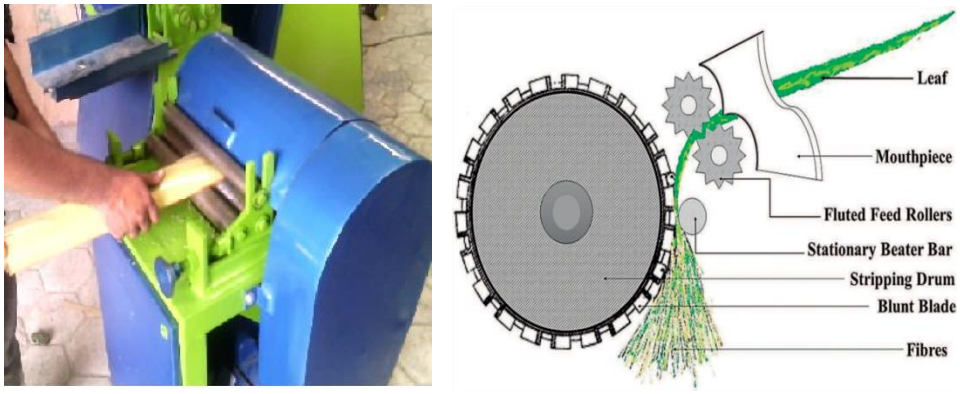


Figure 3 Banana fiber Extraction Machine and Schematic diagram

The below raw banana, treated and cexisting cotton fiber have been used that were collected from the same land. Figure 4 mentioned the three fibers. The banana is coming under the summer variety of South India whereas cotton is coiming under winter irrigation of the same land.

Figure 4 The Raw, Alkali treated and Cotton fiber samples

7. RESULTS AND DISCUSSION

The results and discussion are done from the fiber, sanitary napkin, yarn, and fabric based sequential order.

7.1 Physical Properties

The length, diameter and breaking load of the three fibers report were carried out here. The banana fiber is extracted from the stem; the stem length is almost 7 feet is coming. The fiber cannot be extracted from the 7 feet length, so it was cut as 2 pieces, the bottom is coming under 4 feet whereas top was 3 feet. Then the fiber was extracted

by extraction machine. Hence the length was coming around 0.90 meters to 1.20 meters. Breaking load or tensile strength is also carried out. Cotton fibers length is very small but strength is little bit higher than banana fiber. The ASTM D3822 standard has been followed.

7.2 Chemical Composition

The chemical composition was tested for three fibers. Cotton has very good cellulose content than banana. But the lignin content is very less than banana. Raw banana fiber has very good lignin content than treated banana. The cellulose content has enhanced the crystalline structure of the fiber whereas the amorphous region would be remaining. Banana is generally called as lingo-cellulosic fiber. The composition test has been followed by ASTM D4850 Standard and mentioned in Table 1.

Table 1 Chemical Composition of the Fibers

Chemical Composition	**Fiber Samples (10 samples Mean)**		
(%)	**Raw Banana**	**Alkali Treated**	**Cotton**
Cellulose	57.63	63.34	94.13
Hemi-cellulose	10.81	11.85	1.51
Lignin	12.83	7.84	0.18
Pectin	3.01	2.9	0.32
Others	13.16	12.74	3.72

7.3 Fineness

The fineness has been found out by weight in unit length of 1000 meters of fiber. This is one of the physical properties, but this is playing a major role in textile yarn preparation. So, has been observed separately and has given more important for that. It is explained detailed in fineness property and then the linear density or tenacity also calculated by fineness. The micronnaire (milligram) value is performed according to the fineness. The ASTM D3822 standard has been followed.

7.4 Absorption

The fiber absorption level was carried out for three fibers. The banana has good holding or gaining level than cotton because cotton has good cellulose content but not having lignin content. The availability is very less in cotton. Banana has good lignin content but when it was treated by alkali, the lignin content is dissolved in water. It is discussed in detailed here.

7.5 Antibacterial Test

As per the CTL/SOP/MICRO/004 standards the organism growth level measured. The Chennai Testing Laboratory has followed the standard. The raw banana fiber has good resistance than other two. The test has been performed by 18 hours. The growth measurement is mentioned by millimetre that has given in Table 2. If the growth level is high, that is mentioned by macroscopic observation.

Table 2 The Organism growth observed in three fibers

Timings (hours)	**1**	**5**	**10**	**15**	**18**
	Growth Observed level				
Raw Banana	Nil	Nil	Nil	Nil	0.02mm
Alkali Treated	Nil	Nil	0.01mm	0.02mm	0.04mm
Cotton	0.03mm	0.11mm	0.23mm	0.37 mm	0.63mm

7.6 FTIR and XRD

The organic element's structure is much more important for all kind of fibers. It was observed to identify the significant structure of the fiber. It is mentioned in the peak levels. The absorption and fineness values are most important for making the further product development; The FTIR report has been taken for both (banana) fibers and compared their organic elements. X-ray spectrum of the raw and treated banana was observed to understand the crystallinity nature. The peaks in the spectrum of both fibers were discussed in detail.

Sanitary Napkin performance

7.7 Absorbency

The fiber absorbency level had been studied. Here, the sanitary napkins absorbency level has been tested as per IS 5405:1980 standard. The coloured fluid or the oxalate coat blood has been used. The liquid holding level has checked after flow the liquid on the pad 15ml per minutes.

7.8 Disposability

Fiber disposability level has been tested in the normal water solution. The 15 or 20 litre waters has taken and immersed the used pad in the water solution then it should be disintegrated by some minutes. The IS 5405:1980 standard was followed. It is explained elaborately here.

7.9 pH Value

The pH value is most important for textile products especially for hygienic textiles. The value should be maintained from 6 to 8.5. All apparel industries are maintaining the cloth pH value from 6.8-7.5. However, 6-8.5 is coming under acceptable region. This detailed analysis is discussed here.

7.10 Antibacterial Test

The bacteriostatic value is found here. The value will help to get the organism growth in the fiber. It contains both positive and negative bacteria. The negative growth only was measured and taken their growth level as per the timings. The bacteriostatic value must be less then only the sample has resistance property. This is discussed here detailed.

7.11 Antifungal Test

This is also tested like an antibacterial test. The growth value has been checked as per the timings. The maximum 18 hours have been taken. While the growth is started, the quality of organism growth resistance has been identified in the fibers. Both are tested as per CTL/SOP/MICRO/004 standard. The final consolidated results mentioned in Table 3.

Table 3 The Performance of the Napkin

Parameter	Napkin Samples (6 samples Mean)		
	Raw Banana	**Alkali Treated**	**Cotton**
Absorbency (Should not be any Strain and Leakage)	Pass the Test	Pass the Test	Pass the Test
Disposability (Min)	Pass the Test	Pass the Test	Pass the Test
pH Value	7.1	8.4	7.3
Antibacterial Test (18 Hours)	No-Growth Observed	0.68 mm	Macroscopic Growth Observed
Anti-Fungal Test (18 Hours)	0.03mm	0.81mm	Macroscopic Growth Observed

Mechanical Properties of Yarn and Fabric

7.12 Yarn Twist

The yarns use to prepare two kinds of twist that are S and Z twist. The blended ring spinning yarn has followed S twist and rotor yarn was followed by Z twist. The ASTM D1422 Standard was conducted in both samples. The thickness of both yarn has compared and cotton yarn and explained with all detail.

7.13 Yarn Count

The yarn count has conducted by indirect method. The English count system has been followed. The lea was taken from wrapping reel and checked their weight as per ASTM D1907. The count had taken as per unit weight corresponding to unit length that has denoted in the Table 4. The yarn has good quality when the count value is going up, the standard is coming down while is going down. This can be followed in indirect system for counting of the yarn.

Table 4 Yarn count for blended and pure banana yarn

Sl. No	**Blend Ratio (C:B)**	**Spinning system**	**Count (Ne)**
1	50:50	Ring spinning	20s
2	0:100	Rotor spinning	10s

7.14 Single Yarn Strength Testing

The single yarn was tested by eureka testing machine. The one-meter yarn sample has been taken. The one end of yarn is mounted in the fixed jaw and other end with moving jaw then the machine starts to run and get the yarn strength. The ASTM D2256 standard was followed.

7.15 Yarn Lea Strength Testing

The sample of lea was prepared from wrapping reel. The length of the lea is 120 yards. The circumference of the reel is 1.5 yard. So, there are 80 rotations need to make one lea yarn and discussed with detailed. Standard ASTM D1578-93 has followed.

7.16 Yarn Evenness and Hairiness

The yarn evenness was checked for 1000 meters of the yarn. The AFIS yarn evenness tester has been used to measure evenness, CV%, IPI and hairiness. Additionally, the yarn thick and thin places were observed by this machine. The machine can use for multi- testing of fiber and yarn**.** ASTM D1425 standard has been used. Figure 5 shows comparison of banana and cotton ring and roter spun yarn IPI and hairiness.

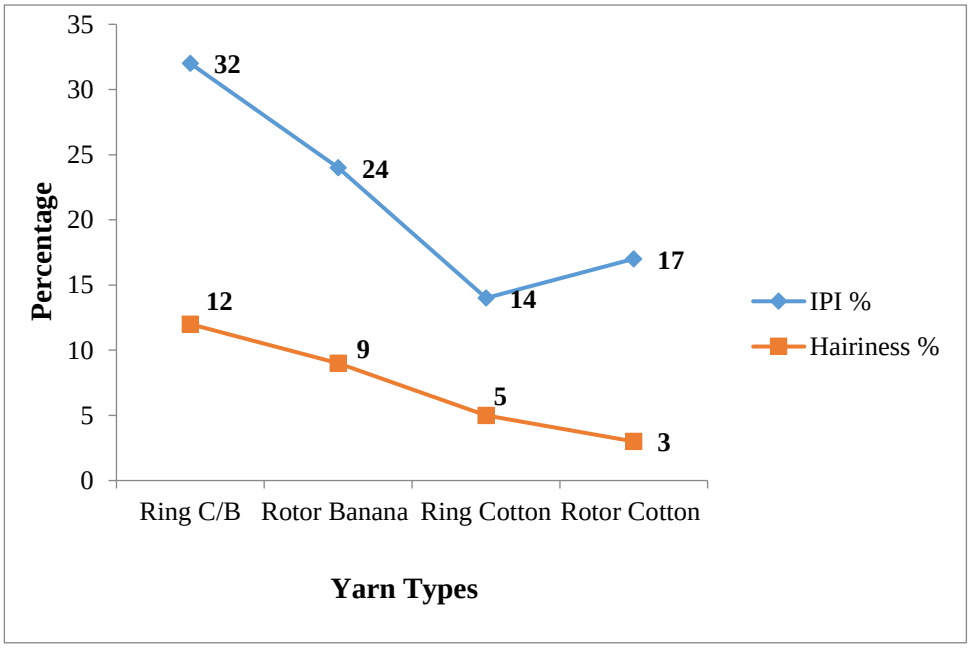


Figure 5 Comparison of banana and cotton yarn IPI and hairiness

7.17 Fabric Thickness

The fabric thickness has been identified by Dial gauge. 4 fabrics were taken in this test. The dial gauge is belonging to yoshido testing equipment from Japan. Thickness was checked in different places in the samples. There are 5 test has been taken in one samples.

7.18 Fabric GSM

Generally, it is called as gram per square meter. This will check the fabric weight. Usually, the GSM cutter has been used and cut the fabric samples in round shape that is equal to the 10cm x10cm square. The samples GSM discussed detailed here.

7.19 Fabric Count

These calculate the no. of ends and no. of picks per inch. The count has been checked 3 places in 1 meter fabric then the average value had taken. The ends are coming vertical wise whereas the picks are under horizontal.

7.20 Fabric Tensile Strength

The fabric samples prepared first and then fix the samples in the fixed as well as moving jaw. After that the machine starts to run and get the tensile strength. The samples preparation would be warp and weft basis, the sample must be 75mmx45mm.

7.21 Fabric Tearing

The fabric samples prepared first and then fix the samples in the fixed jaw. After that the machine has pendulum, by that, the fabric will tear that value should be noted. The samples preparation would be warp and weft basis, the sample specimen must be 60mmx 35mm.

8. ORGANIZATION OF THESIS

Chapter 1: Introduction

This chapter provides an overall view of the Natural fibers, its classifications, advantages, and applications. It is briefly explained about the discussion of cotton fiber

and other fibers such as banana, ramie, flax and bamboo. The discussion initiative was about the alternative of cotton in textile industries. The banana has been chosen and measured biomass of banana fibers. The fibers were extracted and treated with 4% NaOH then compared their properties with cotton. The napkin has been developed from raw banana, treated banana and cotton, and compared their performance. The yarn was prepared from only alkali treated fiber because it has got good fineness for blending. The fabric was manufactured from cotton and banana yarn, here cotton used as warp whereas banana yarn used as weft. Finally, their mechanical properties were discussed and compared with cotton yarn and fabric.

Chapter 2: Literature Review

This chapter provides the information about the recent literature review on different types of natural fibres and its characteristics. The study extends to select a suitable natural fiber, their biomass, fiber extraction, extraction machines, recovery level, product development, process parameters and its influence on their mechanical properties. Further, this chapter discuss about the literature on eco-friendly sanitary napkin, yarn, and fabric preparation from natural fibers. The product development, process flow chart and by-product properties have also been gone through from the literatures. The product development is compared with other literature and what kind of techniques and equipments have been followed and time duration, amount of fiber, sheath models has also been studied.

Chapter 3: Materials and Experimental Details

Cotton is playing a major role in textile industries. It is taken as existing samples in this research. The fiber comparison studies have been followed for 3 fibers and check the performance. The required machineries have been given for fiber extraction then the banana fiber treated material, machines and experimental details have been mentioned. The banana yarn and fabric were manufactured by spinning and weaving machines. Those machines have been discussed in detail and the product is tested by testing equipment. The testing machines, details, equipment are discussed elaborately.

Chapter 4: Property Comparison Studies between Banana, Treated Banana, and Cotton Fibers

This chapter describes the physical, chemical composition, absorption, fineness, and antibacterial properties of banana, treated banana and cotton fibers. The properties had been studied and compared with one another and checked their performance. The ASTM and AATCC Standard have been followed.

Chapter 5: Sanitary Napkin Absorbency, Disposability, pH value and Antibacterial Test

This chapter describes about sanitary napkins that were prepared from both banana and cotton fibers. As per IS standards, their performance had been checked with some aspects such as absorbency level, disposability, pH and antibacterial test. But not having much difference between both. As per the CTL/SOP/MICRO/004 standard, the napkins antibacterial test has been tested.

Chapter 6: Mechanical Properties of Banana Yarn

This chapter deals with yarn process flow chart and their mechanical properties. There are two kinds of yarn were made form banana fiber. The 50:50 cotton blended yarn and 100% banana yarn has been produced. The yarn has been tested by different testing equipment with their ASTM standards and compared with 100 % cotton yarn. That is discussed in detailed here.

Chapter 7: Mechanical Properties of Banana Fabric

This chapter deals with fabric process flow chart and their mechanical properties. There are two kinds of fabric were made form banana yarn that were from ring and rotor spinning yarn. Both banana yarns were used as filling yarn or weft yarn in fabric. The cotton was used as warp yarn. The fabrics have been tested by different testing equipment with ASTM 6797-15 standards and discussed in detail. The banana fabric mechanical properties were compared with 100% cotton fabrics with same count.

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LIST OF PUBLICATIONS

1. **J. Dhesinghraja,** K. Mayandi, N. Rajini, and C. Prakash, A potential renewable energy resource from the biomass of banana pseudo-stem (*Musa acuminata*) wild species variety, *Biomass Conversion and Bio-refinery*, **12** (2) (2023), 234-241.

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3. **J. Dhesinghraja,** K. Mayandi, N. Rajini, and C. Prakash. Biowaste Management Comparative Analysis between Banana and Bamboo Fibers (*Musa acuminata* and *Bambusa vulgaris*), ***BioResources*** , **19** (1) (2024), 1245-1259.

4. **J. Dhesinghraja,** K. Mayandi, A. Selvakumar and M. Murali, Eco- friendly Sanitary napkin, *Asian Textile Journal*, **31** (8) (2022), 34-40.

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6. **J. Dhesinghraja**, K. Mayandi, and M. Murali. A sustainable raw material for product development, *Emerging Trends in Business and Technology for Sustainable Growth*, **13** (2022) 20-34, **ISBN: 978-81-956844-1-0,** *Book Chapter*.

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